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Temporal and spatial distribution of ancient sites in Shaanxi Province using geographic information systems (GIS)

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Abstract

Revealing the evolutionary history of the relationship between humans and Earth will help us understand the spatial and temporal distribution of ancient cultural sites (referred to as ancient sites). This research explored the spatial and temporal distribution of ancient sites in Shaanxi Province (China) from the Han Dynasty to the Tang Dynasty and assessed their correlation with the natural environment and economic patterns using geographic information system (GIS) technologies. The results indicated that (1) the ancient sites in the two periods were mainly centered in Xi'an based on kernel density analysis. The number of ancient sites in the Han to the Northern and Southern Dynasties was greater than that in the Sui and Tang Dynasties. The spatial distribution of ancient sites indicated that more sites are present in northern Shaanxi Province than in the south. (2) The ancient sites in Shaanxi Province were concentrated in the plain area with an elevation of approximately 866 m; the aspects were south, east, and southeast; and the slopes were 0 ~ 3° based on an analysis of the topographic features. (3) The ancient sites were concentrated within 10 km of the river. Fewer ancient sites were distributed with increasing distance from the river, indicating a linear distribution of ancient sites.

Keywords: Shaanxi Province, Ancient sites, GIS, Spatial analysis, Temporal and spatial distribution

Introduction

Archaeological findings show that the evolution of ancient human settlements and the development of cultural history are closely related to the natural and social environments. Ancient sites refer to the ruins of ancient structure remains and the traces left by human modification of the natural environment [1]. Revealing the relationship between ancient humans and the land by analyzing the temporal and spatial distribution of ancient sites and the factors affecting their environmental evolution is a helpful endeavor. Furthermore, this information can be used to better explain the selection strategies and adaptations of ancient humans to the environment, and it also has reference significance for the coordination of modern human-land relations. The natural environment is the foundation of the social environment [2]. Natural environmental changes have profound effects on human migration [3], agriculture [4], social patterns [5], and the changes in ancient dynasties [6]. Therefore, it is helpful to understand the human-Earth relationship in that period on a geographical scale by studying the correlation between ancient sites and the natural environment in a historical period.

Previous studies of ancient sites mainly focused on exploring the relevance of ruins to natural environmental factors [7, 8] and human activities [9]. Research on ancient sites in China has concentrated on periods from the Neolithic [10] to the Han Dynasty [11]. Due to the technical limitations of traditional archeology and history, new technological methods of spatial analysis have attracted the attention of scholars [12–15]. Currently,

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GIS technology and related analysis methods are being widely used in the study of ancient sites [16–18], such as in research on the analysis of settlement patterns [19], the spatial and temporal evolution of ancient sites [20], and the specific factors affecting site distribution [21]. Research on ancient sites in Shaanxi Province has mainly focused on history, archaeology, anthropology, and sedimentology; in contrast, few studies have been conducted from a geographic perspective.

This research collected data on ancient sites and established a database during the historical period in Shaanxi Province, China. The spatial analysis method of GIS was used to analyze the ancient sites in the study area in terms of elevation, distance from the river, slope, and aspect. We examined the spatial and temporal distribution of ancient sites in Shaanxi Province from the Han Dynasty to the Tang Dynasty and considered the natural and human factors in Shaanxi Province. Exploring the relationship between human activities and the evolution of the natural environment during this period is of referential significance for reconstructing the relationship between man and land during the historical period in Shaanxi Province and for exploring the rules of human cultural development and evolution.

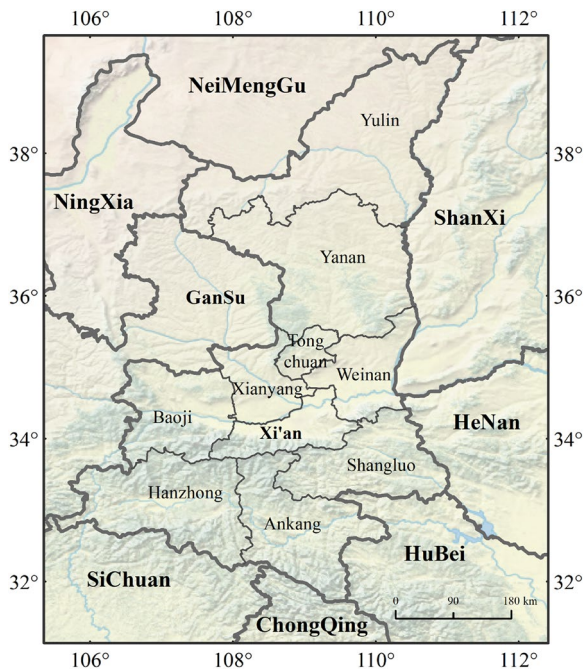

Fig. 1 Geographical location of Shaanxi Province, China

Methodology

Study area

Shaanxi Province is located in Northwest China and has ten prefecture-level cities (Fig. 1). It borders the seven provinces of Shanxi, Henan, Hubei, Sichuan, Gansu, Ningxia, Neimenggu, and the municipality of Chongqing. A warm-temperate semi-humid climate dominates the northern Shaanxi Plateau, while the Guanzhong Plain belongs to the north subtropical humid climate, and Qinba Mountain has a warm-temperate humid environment. Affected by the topography, the annual precipitation is lower in the north and higher in the south, increasing from 300 mm in the north of Shaanxi to 1700 mm in the Qinba Mountains. Shaanxi Province is the gateway to Northwest China. Its geographical location is critical and has always been a strategic military location. Ancient sites formed by cultural blending require the attention of experts and scholars.

Data sources

The data on ancient sites mainly came from the third national cultural relics census series in Shaanxi Province [22]. This book consisted of 11 rolls and 107 volumes and was compiled by the Shaanxi Provincial Bureau of cultural relics; the compilation process took four years, and more than 6000 professional and technical personnel were employed for field investigation. Therefore, these series of books are particularly worthy of study, and the data in the books are more reliable. The spatial data for ancient sites were obtained from archaeological surveys and excavation briefs that describe ancient sites in the literature, and then we found the corresponding location on Google Earth. It is worth noting that a few ancient sites with unclear descriptions were abandoned in the process using the GIS data conversion tool to import site points into ArcMap. In addition, we have some vector data and raster data. The vector data were obtained from the 1:4 million Shaanxi administrative line and the area data provided by the official website of the National Center for Basic Geographic Information. The raster data were obtained from the digital elevation model (DEM) data of Shaanxi Province with a resolution of 30 m provided by the Geospatial Data Cloud Platform.

It is necessary to explore the temporal and spatial distribution of ancient sites in Shaanxi Province from the Han Dynasty to the Tang Dynasty while considering the influence of the natural geographical environment on spatial distribution. Therefore, we selected the DEM data and administrative boundaries as the essential data to analyze ancient sites' temporal and spatial distribution patterns. However, the geographical environment in the historical period is not available. Although there were differences between the natural geographical environment of modern Shaanxi Province and that of the Han Dynasty or the Tang Dynasty, the current geographical environment evolved based on the historical environment, and

the overall framework did not significantly change. Therefore, we used the current geographical data to explore ancient sites' temporal and spatial distribution. Referring to the historical classification of the chronology system and archaeology system, this study examines the ancient Chinese historical period (206 B.C.–907 A.D.), spanning 1112 years. Furthermore, we divide this period into two subperiods: the Han to Southern and Northern Dynasties (206 B.C.–581 A.D.) and the Sui and Tang Dynasties (581–907 A.D.).

The framework of the method

Since the emergence of geographic visualization, humans have begun to use different spatial analysis methods to analyze spatial features [23]. A synthesis of scholars' research results suggests that spatial analysis is a technique and method that includes the spatial location information of objects in the analysis, including spatial data analysis, spatial statistics, and modeling. Spatial analysis capability is the critical technology of GIS, and it is one of the main features that distinguishes GIS from general digital mapping systems [24]. Spatial analysis methods include kernel density, reclassification, buffer analysis, and distance analysis [25]. Figure 2 illustrates the framework of the research method. We explore the relationship between the ancient sites' distribution and the geographical environment by combining natural and human factors such as topography, climate and precipitation, regime change, economic development, and population.

First, we located the latitude and longitude of ancient sites on Google Earth based on the textual description (including location and attributes) in the third cultural relics census in Shaanxi Province and converted it to ESRI shapefile format in ArcMap. We established a database of ancient sites in Shaanxi Province in the catalog database of the GIS software, which was used to store the location, period, and area of the ancient sites. The historical periods studied in this paper were divided into (1) Han to Southern and Northern Dynasties and (2) Sui and Tang Dynasties. We imported the administrative boundaries and DEM data of Shaanxi Province into ArcMap. The elevation, slope, and aspect data were obtained through the reclassification of the DEM data.

Second, we used the spatial analysis methods of GIS to explore the temporal and spatial distribution of ancient sites. More specifically, the spatial analysis tools of ArcMap were used to identify and overlay the ancient sites, map the temporal and spatial distribution of the two periods, and calculate the statistical results of ancient sites at different elevations, slopes, and aspects. The kernel density method was used to explore the spatial distribution of points through the change in the point density in the study area, which is given as follows:

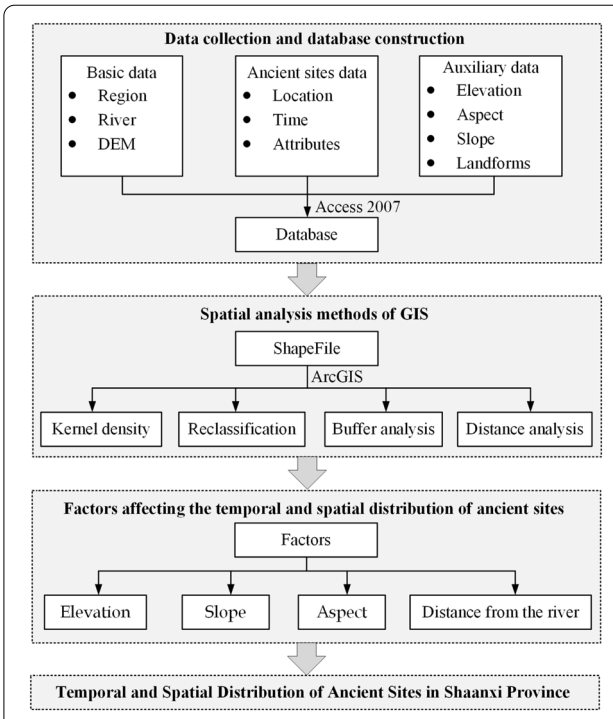

Fig. 2 The framework of the method

$$\hat{f}(x) = \frac{1}{nh^d} \sum_{i=1}^{n} K\left(\frac{x - x_i}{h}\right) \tag{1}$$

where n is the number of ancient sites, d is the number of dimensions, and $x - x_i$ is the distance from the estimated point to the sample point. Several studies have indicated that the choice of the spatial weight function has little effect on the point pattern distribution results. It is essential to note the selection of the distance attenuation threshold [26].

Third, we used the above spatial analysis methods to explore the factors that influenced the spatial and temporal distribution of the ancient sites. We used DEM data and overlaid the elevation, slope, and aspect of the study area with the geographic locations of the ancient sites with GIS spatial analysis techniques. In addition, buffer analysis was used to discuss the distance between the ancient sites and the river.

Analysis

Temporal and spatial distribution of ancient sites using kernel density analysis

We compiled information from the third cultural relics census in Shaanxi Province. The types of ancient sites in this study include ancient city sites, city wall ruins, beacon tower sites, channel sites, and ancient kiln sites. A total of 1937 ancient sites were considered, including

1594 ancient sites in the Han to the Southern and Northern Dynasties and 374 ancient sites in the Sui and Tang Dynasties; additionally, 31 ancient sites spanned the two periods. This study explored the spatial distribution of ancient sites through the spatial analysis method of GIS and then observed whether the ancient sites were spatially aggregated. The kernel density analysis tool was used to analyze the density of ancient sites. A pixel size of 0.1 m and radius of 1 km were selected as the search area after many experiments. The kernel density results are shown in Fig. 3.

Temporal distribution of ancient sites

Regarding the number of ancient sites, 82.3% were in the Han to the Southern and Northern Dynasties. The Han Dynasty (206 B.C.–220 A.D.) was a unified empire in China, with a prosperous economy and culture and a large population. During the Three Kingdoms (220–280 A.D.), the Eastern Jin Dynasty (317–420 A.D.), and the Southern and Northern Dynasty (420–581 A.D.) periods, Chinese society was turbulent, and the population decreased sharply due to war, famine, and pestilence [27]. From the Han Dynasty to the Tang Dynasty, a total of 367 wars occurred between agricultural and nomadic groups, 76% of which occurred during the Han to Northern and Southern Dynasties, and the remaining 24% occurred during the Sui and Tang Dynasties [28]. The ancient sites were related to ancient defense facilities, such as ancient city walls and beacon sites; thus, the number of these sites is closely related to warfare.

In addition, climatic factors played an essential role in transforming ancient humans from a hunting lifestyle to an agricultural lifestyle. In some cases, extreme climate fluctuations may have triggered wars between the farming and nomadic groups, resulting in important historical societal or dynasty changes or even collapse [29, 30]. During the Eastern Han Dynasty (25–220 A.D.) and Northern and Southern Dynasties (420–581 A.D.), nomads occupied parts of northern China. The historical period from the Han Dynasty to the Southern and Northern Dynasties was dry, cold, and harsh, with many changes in dynasties [31]. In contrast, the climate was warm, and society was stable during the Sui and Tang Dynasties. However, this period lasted only 300 years. Therefore, ancient sites of the Sui and

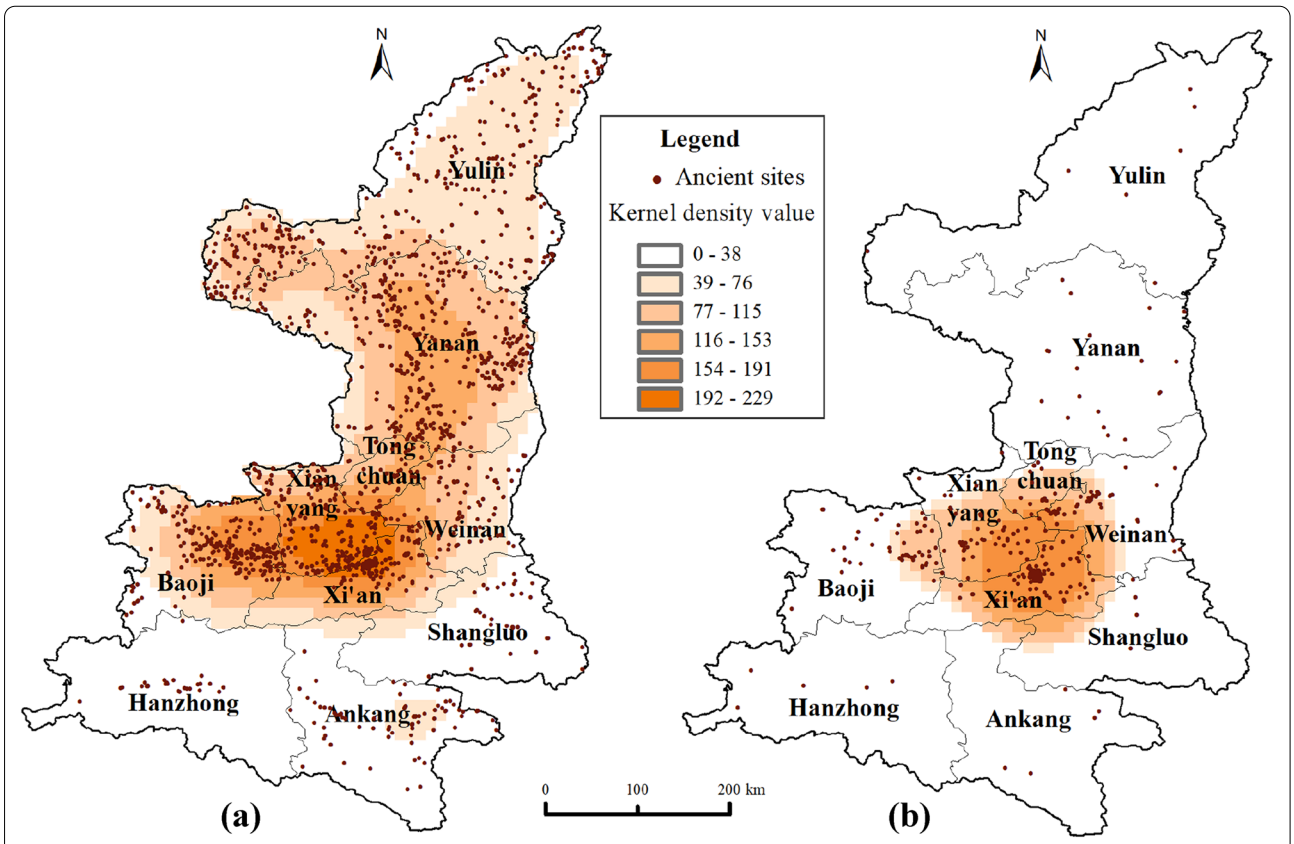

Fig. 3 Kernel density analysis of ancient sites. **a** Distribution of ancient sites in the Han to Northern and Southern Dynasties. **b** Distribution of ancient sites in the Sui and Tang Dynasties

Tang Dynasties were far fewer than those from the Han Dynasty to the Southern and Northern Dynasties.

Spatial distribution of ancient sites

The ancient sites in Shaanxi Province are concentrated in the Guanzhong Plain (e.g., Xi'an, Xianyang, and Baoji) and the Northern Shaanxi Plateau (e.g., Yanan). In ancient times, people revered and lived in the natural environment with a low ability to transform it. People chose to live in groups, help each other, and resist natural disasters; thus, the ancient sites presented the characteristics of an aggregated distribution. The ancient sites distributed in southern Shaanxi Province in the two periods were few and irregular. Notably, travel in the mountainous area of southern Shaanxi Province is inconvenient, and the area has a small full-time population. In addition, more ancient sites were distributed in northern Shaanxi than in southern Shaanxi. Specifically, northern Shaanxi is located at the intersection of nomadic and agrarian cultural zones, and cultural integration often led to the creation of ancient sites. In addition, compared to those for the Han to the Northern and Southern Dynasties, ancient sites for the Sui and Tang dynasties are more concentrated in the area centered around Xi'an. Xi'an was the Chang'an of the Sui and Tang Dynasties, and as the political, economic, and cultural center at the height of ancient China, it had a developed economy and a large population.

In summary, the temporal and spatial distribution of ancient sites are closely related to the topography, regime changes, natural environment of Shaanxi Province.

Factors affecting the temporal and spatial distribution of ancient sites

In ancient society, people relied heavily on the natural environment, especially the geographical environment. Therefore, the elements that affected the distribution of ancient sites in this paper included elevation, slope, aspect, and distance from the river. (1) Elevation directly impacts climate, precipitation, landform, economy, and habitability. (2) Slope relates to the height of the terrain. The low slope of a plain or basin is more suitable for people to live, while the large slope of a mountain is less suitable for people to live. (3) Aspect involves sunlight illumination. In Shaanxi Province, the south, southwest, and southeast directions are mostly more habitable sunny slopes, while the east, west, and northeast directions are mostly less habitable shady slopes. (4) Rivers are closely related to ancient human activities. Influenced by water extraction techniques, ancient humans lived within a certain distance from the closest river and used water for everyday life and agriculture [32]. Additionally, since humans were more vulnerable to flood risk when settling near rivers, sites are often selected at some distance from the nearest river [33].

Elevation

In ArcMap software, the DEM of Shaanxi Province was projected and symbolized. Then, the spatial data of ancient sites from the Han Dynasty to the Tang Dynasty were overlaid on the DEM. Finally, the distribution of ancient sites at different elevations was mapped (Fig. 4). Furthermore, we identified the elevation of ancient sites and counted the frequency of ancient sites at different elevations, as shown in Fig. 5.

The results showed that 176 (11.0%) ancient sites were distributed at elevations between 200 and 400 m during the Han to the Northern and Southern Dynasties, and 33 (8.8%) ancient sites were distributed at elevations between 200 and 400 m during the Sui and Tang Dynasties. 445 (27.9%) ancient sites during the Han to the Northern and Southern Dynasties and 252 (67.4%) ancient sites during the Sui and Tang Dynasties were distributed at elevations between 400 and 800 m. A total of 589 (36.9%) ancient sites during the Han to the Northern and Southern Dynasties and 69 (18.4%) ancient sites during the Sui and Tang Dynasties were distributed at elevations between 800 and 1200 m. A total of 339 (21.2%) ancient sites during the Han to the Northern and Southern Dynasties and 19 (5.1%) ancient sites during the Sui and Tang Dynasties were distributed at elevations between 1200 and 1600 m. In addition, 48 ancient sites during the Han to the Northern and Southern Dynasties and an ancient site in the Sui and Tang Dynasties were distributed at an elevation above 1600 m, accounting for 3.0 and 0.3% of the total number of ancient sites in each period, respectively. The number of ancient sites decreased with increasing elevation above 1200 m in both periods.

Ancient sites were distributed at an average elevation of 917.8 m in the Han to North and South Dynasties. In comparison, the ancient sites were distributed at an average elevation of 637.0 m in the Sui and Tang Dynasties. Floods are among the world's most devastating natural disasters, causing enormous damage and death. With social progress and technological development, people's ability to manage floods and develop agricultural irrigation techniques has improved tremendously [34]. The period from the Han to the North and South Dynasties was more seriously affected by floods than was that for the Sui and Tang Dynasties. Floods have also dramatically changed agricultural conditions, thus prompting people to move to higher elevations [35]. From the Han Dynasty to the Tang Dynasty, the ancient site with the lowest elevation was Shujilou (222 m) in Shangluo city. The ancient site with the highest elevation was Maliantan (1957 m) in

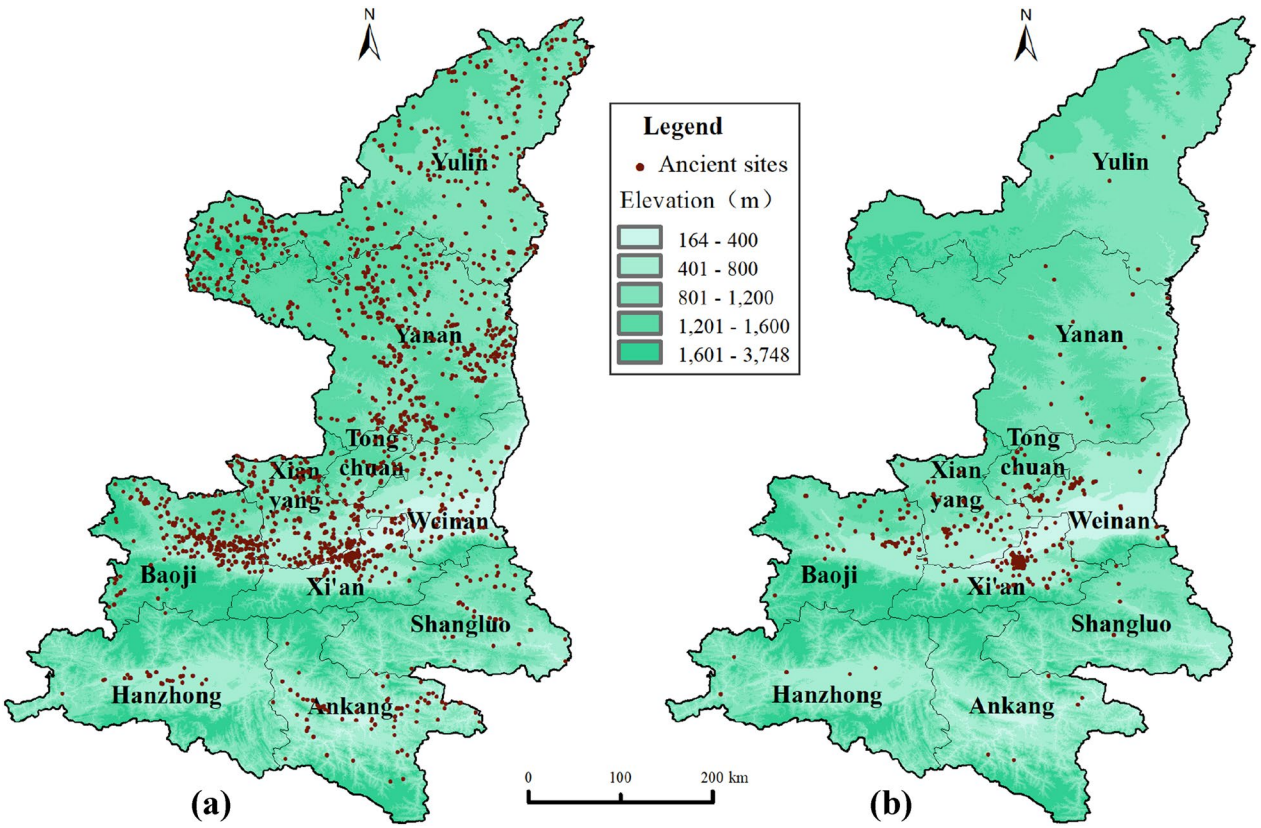

Fig. 4 Elevation analysis of ancient sites. **a** Distribution of ancient sites in the Han to Northern and Southern Dynasties. **b** Distribution of ancient sites in the Sui and Tang Dynasties

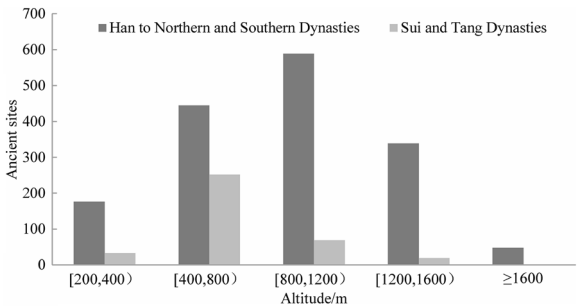

Fig. 5 Distribution of ancient sites at different elevations

Baoji city. Thus, the ancient sites in the two periods were distributed between 222 and 1957 m, with an average elevation of 866.2 m. The spatial distribution of ancient sites was correlated with elevation. The distribution of ancient sites decreased with increasing elevation above a certain elevation threshold (1200 m). This result indicates that ancient humans were less active at high elevations, which is consistent with the stronger dependence of ancient humans on the natural environment.

Slope

The slope represents the direction of the terrain (Fig. 6). The smaller the slope is, the flatter the terrain is, but the larger the slope is, the steeper the terrain is [36]. Slope directly affects people's choice of where to live, with plain areas being more suitable for people to live in than mountainous areas. In addition, slope affects the degree of river erosion on the ground. The slope of the large flow rate and the severe decline in surface scouring lead to soil erosion and are not conducive to the growth of crops. In contrast, if the slope is small and the flow rate is low, the nutrients in the soil are easily deposited for the development of crops. Therefore, slope influences people's choice of where to live.

The slope data were extracted by ArcMap from the DEM of Shaanxi Province (as illustrated in Table 1). The slope was classified into five levels by the slope grading index: flat slope (0–3°), gentle slope (3–10°), medium slope (10–25°), steep slope (25–50°), and sharp slope (> 50°). We mapped the distribution of the ancient sites in two periods on different slopes based on the slope change. The results showed that the ancient sites were distributed in areas with an average slope of 7.1° in the

Han to North and South Dynasties, and ancient sites were distributed in areas with an average slope of 4.3° in the Sui and Tang Dynasties. Most ancient sites were distributed on flat slopes in the two periods, accounting for 42.7 and 63.6% of the total, respectively. The number of ancient sites tended to decrease with increasing slope. The proportion of ancient sites distributed on the middle and steep slopes in the Sui and Tang Dynasties was significantly reduced compared with the proportion in the Han to Northern and Southern Dynasties. The results showed that the ancient sites of the Sui and Tang Dynasties were more distributed in areas with less undulating terrain. People chose to live on flat and gentle slopes, and the analysis results were more consistent with the actual situation.

Aspect

Aspect is one of the geomorphological forms that significantly influences the mountain climate and precipitation. Shaanxi Province is located in the Northern Hemisphere. The southern slope facing the sun in the Northern Hemisphere receives more radiation than does the northern slope. Hence, people in the Northern Hemisphere prefer to choose southern, southwestern, or southeastern slopes to build on and obtain maximum light. We classified slope orientation into four categories according to the degree of suitability for living: most suitable (south), suitable (southeast and southwest), relatively suitable (northwest and north), and unsuitable (east, west, and northeast) [37].

In this paper, we extracted the data on ancient sites distributed at different aspects using GIS technology. In addition, we drew a statistical map of ancient sites distributed in the various aspects (as illustrated in Fig. 7) and a statistical table of ancient sites distributed in different levels of suitable area (as shown in Table 2). Most ancient sites were distributed in livable areas from the

Table 1 Statistical results of ancient sites distributed on different slopes

Slope/°	0–3	3–10	10–25	25–50
From Han to North and South Dynasties	42.7%	26.7%	28.1%	2.5%
Sui and Tang Dynasties	63.6%	23.3%	11.8%	1.3%

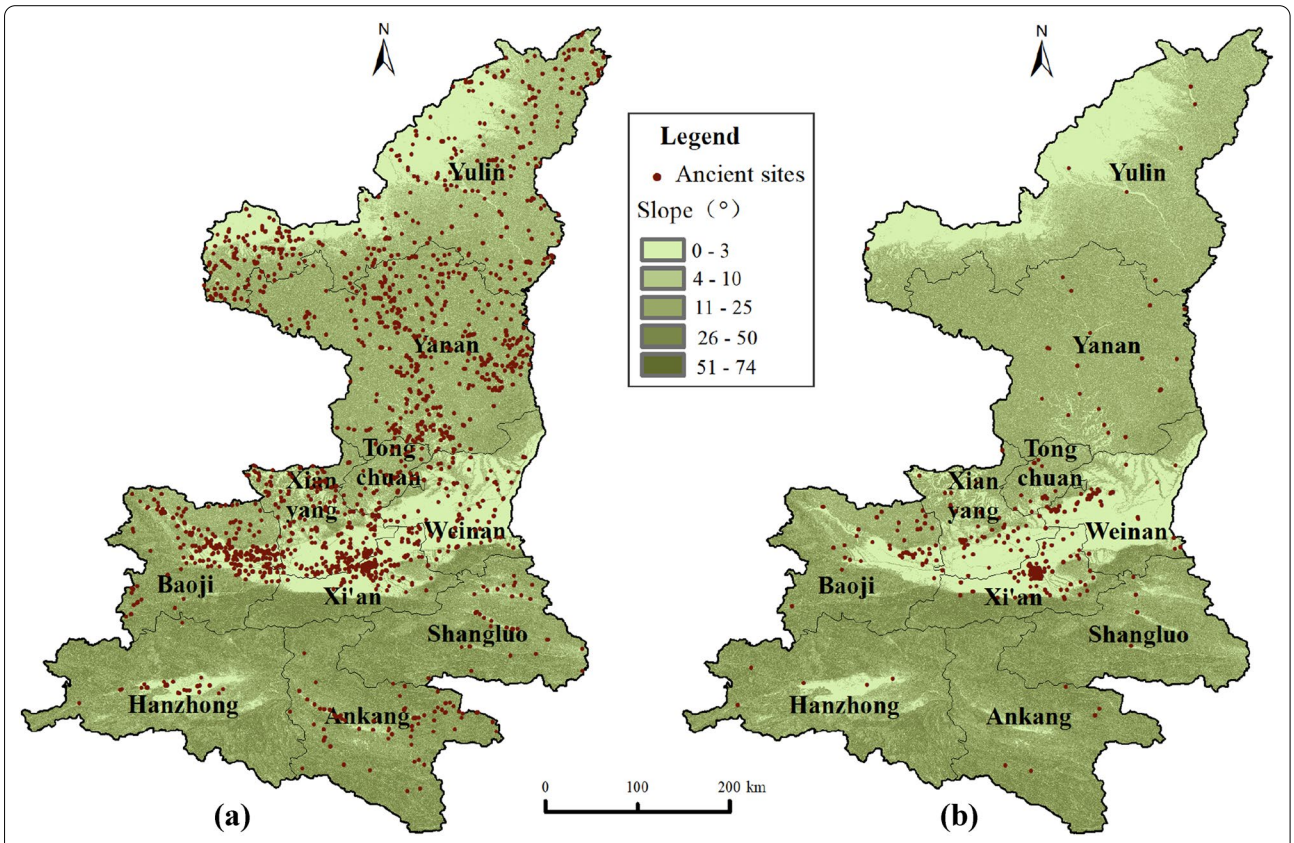

Fig. 6 Slope analysis of ancient sites. **a** Distribution of ancient sites in the Han to Northern and Southern Dynasties. **b** Distribution of ancient sites in the Sui and Tang Dynasties

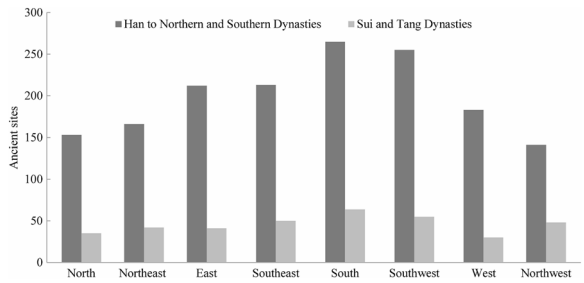

Fig. 7 Distribution of ancient sites in different aspects

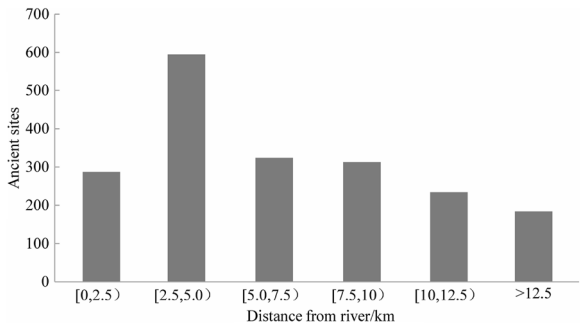

Fig. 8 Distribution of ancient sites at different distances from the river

Han Dynasty to the Tang Dynasty, accounting for 16.8% of ancient sites. The percentages of ancient sites distributed at the most suitable, suitable, relatively suitable, and unsuitable aspects were 16.8, 29.3, 19.3, and 34.5%, respectively. The results showed that 65.5% of the ancient sites were distributed in habitable aspect zones. Influenced by subjective variability, a small number of the aspects were uninhabitable. This result is consistent with the previous analysis that ancient people preferred aspects that received relatively more solar radiation. Academics generally believe that ancient humans fully accounted for the impact of aspect on production and life when selecting a place to live. From the above analysis, most ancient sites were located in a more suitable aspect. This result leads to the conclusion that the topography of Shaanxi Province changed relatively little from the Han Dynasty to the Tang Dynasty.

The distance from rivers

Since it was troublesome to fetch water manually in ancient times, people lived close to rivers. Human civilization also spread along rivers. However, people do not choose to live in areas too close to rivers because they are prone to flooding. Generally, people preferred to live near but not close to the river, usually within 10 km [38]. The buffer zone of rivers in Shaanxi Province was analyzed using GIS technology. Then, a statistical map of the distance between the distribution of ancient sites and rivers from the Han Dynasty to the Tang Dynasty was drawn (as illustrated in Table 3 and Fig. 8).

The results showed a close relationship between the distribution of ancient sites and the distances to the river from the Han Dynasty to the Tang Dynasty. A total of 78.6% of ancient sites were concentrated within 10 km of the river. The distribution rule is that fewer ancient sites are distributed with increasing distance to the river. The number of ancient sites decreased gradually with increasing distance from the river and was characterized by a linear distribution. Compared with the ancient sites of the Han to the Northern and Southern Dynasties, the ancient sites of the Sui and Tang Dynasties were distributed at sites farther from the river. In the Sui and Tang Dynasties, the inhabitants were less dependent on rivers, and flood control technology was more advanced than that for the Han to Northern and Southern Dynasties. Additionally, people invented a "vertical well" to collect water during the Tang Dynasty, reducing their dependence on rivers.

Results and discussion

This paper discussed the differences in the spatial and temporal distribution of ancient sites from different periods based on previous studies. We analyzed the spatial distribution of ancient sites in Shaanxi Province from the Han Dynasty to the Tang Dynasty and their influencing factors using GIS technology. The main findings are as follows.

(1) The ancient sites from the two historical periods had similarities and differences in terms of their number and distribution range. Specifically, ancient sites from the Han to Northern and Southern Dynasties were concentrated in Xi'an and Xianyang city and less distributed in southern Shaanxi Province. Ancient sites in the Sui and Tang Dynasties were concentrated in Xi'an and Xianyang and scattered in other areas. Influenced by topography, economic development, and other natural and human factors, ancient sites had the characteristics of an aggregated distribution from the Han Dynasty to the Tang Dynasty.
(2) Once the elevation exceeded 1200 m, the number of ancient sites in the two periods decreased with increasing height. Ancient sites were distributed at an average elevation of 917.8 m in the Han to North and South Dynasties. In contrast, ancient sites were distributed at an average elevation of 637.0 m in the Sui and Tang Dynasties. All ancient

Table 2 Statistical results of ancient sites distributed in environments with different suitability

Suitability for living	Most suitable	Suitable	Relatively suitable	Unsuitable
Han to North and South Dynasties	16.7%s	29.5%	18.5%	35.3%
Sui and Tang Dynasties	17.5%	28.8%	22.7%	31.0%

Table 3 Statistical results of the distance between ancient sites and rivers from the Han Dynasty to the Tang Dynasty

Distance/km	0–5	5–7.5	7.5–10	10–12.5	> 12.5
Percentage/%	45.6	16.8	16.2	12.1	9.3

sites were distributed at elevations between 222 and 1957 m in Shaanxi Province, with an average elevation of 866.2 m. The distribution of ancient sites was closely related to elevation, and the number of ancient sites decreased with elevation above a threshold. This result indicates fewer ancient human activities at high elevations, which is consistent with the relatively strong dependence of ancient humans on the natural environment.

(3) Ancient sites were distributed on an average slope of 7.1° during the Han to Northern and Southern Dynasties. Ancient sites were distributed on an average slope of 4.3° during the Sui and Tang Dynasties. Most sites were distributed on flat slopes from the Han to the Northern and Southern Dynasties and in the Sui and Tang Dynasties, accounting for 42.7 and 63.6% of the total, respectively, and the number of sites showed a decreasing trend with the increasing slope.

(4) The distribution of ancient sites was closely related to the distance to the closest river. The ancient sites were concentrated within 10 km from rivers, and fewer sites were distributed with increasing distance from the river. In addition, their distribution had a linear characteristic.

Conclusions

Research on the relationship between humans and nature is the focus of academic inquiry. There is limited research related to the historical geography of ancient sites in Shaanxi Province during the historical period. This paper attempted to summarize the characteristics of human-nature relations in Shaanxi Province from the Han Dynasty to the Tang Dynasty by studying the temporal and spatial evolution characteristics of ancient sites and their influencing factors. Furthermore, this paper analyzed the temporal and spatial characteristics of ancient sites in Shaanxi Province from the Han Dynasty to the Tang Dynasty. More specifically, we explored the relationship between human activities and the natural environment. However, there are some limitations to this study. First, due to the lack of ancient natural environment data, there are limitations to truly reflecting the changing characteristics of the natural environment in the study area. Second, the spatial data from ancient sites were obtained from the third cultural relic census data of Shaanxi Province from 2007 to 2011, which were the most recent census data available.

Our work also indicated that GIS technology could provide new methods and ideas for studying cultural geography by using spatial analysis methods and visual representation. However, due to the lack of historical data, it was difficult to explore the factors influencing the spatial and temporal distribution of ancient sites from the perspectives of historical population data and natural disasters. Therefore, the factors affecting their distribution patterns will be the direction of future research.

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LZ, Overall work guidance and management, Writing-review & editing; ZL, Full text writing; HS, Data analysis and visualization; XW, Organization of the article structure.

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Availability of data and materials
The data of ancient sites in this paper are sourced from the "Third National Cultural Relics Census Series in Shaanxi Province
Vector data source National Basic Geographic Information Center official website: http://www.ngcc.cn/ngcc/
Raster data source of geospatial data cloud platform: http://www.gscloud.cn/
ArcGIS software source: https://desktop.arcgis.com/en/

Declarations

Competing interests
The authors declare no conflict of interest.

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